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Two new dipluran species unearthed from subterranean habitats of the Canary Islands (Arthropoda, Hexapoda, Entognatha)

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Abstract

Two new dipluran species of the family Campodeidae have been unearthed in the Canary Islands. *Remycampa herbanica* **sp. nov.** was found in a highly threatened lava tube on Fuerteventura island. It is related to the soil-dwelling northwest African *Remycampa launeyi* that also inhabits four of the Canary Islands. The two known *Remycampa* species are characterized by a torsion of the labial palps. They differ chiefly in the distribution of macrosetae and in the features of cave adaptation of *R. herbanica*, i.e. elongation of body and appendages, and a higher number of olfactory chemoreceptors with a coniform shape unique within campodeids. *Spaniocampa relicta* **sp. nov.** was collected in the mesovoid shallow substratum (MSS) and has been assigned to a formerly monotypic genus that includes the soil-dwelling *Spaniocampa prima* from the Republic of Guinea. The two species differ in the number of abdominal macrosetae. Females of *S. relicta* **sp. nov.** have small setae arranged in groups along the posterior border of the first urosternite. These structures of unknown function have never been described in other campodeid species. Sequencing the COI barcode region of *R. herbanica* has been produced but it proved insufficient to identify closest relatives. The two new hexapods from subterranean habitats raise the Canarian campodeid fauna to six species. Five of them are living in soil and/or MSS, whereas the cave-adapted *R. herbanica* is known only from a single, particularly endangered lava tube distant from other caves.

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Keywords
Campodeidae, cave-adapted fauna, DNA barcoding, mesovoid shallow substratum, new species, *Remycampa*, *Spaniocampa*

Introduction

With almost 1000 known species, Diplura are the second most diverse Entognatha after Collembola (Deharveng and Bedos 2018). All Entognatha like diplurans are good examples of successful colonizers of hypogean habitats, thriving in all kinds of cryptic environments without light (Condé 1955; Racovitz⊠ 1907), including caves reaching the deepest habitats in the continental crust (Sendra et al. 2020). Furthermore, diplurans have a series of regressive adaptive features common to cave-dwelling animals, given their thin and almost completely unpigmented cuticle and absence of external eyes. However, they have remnants of lateral sense organs, each lying below the integument at both sides of the head in latero-ventral position, which presumably have a light-perceptive function (George 1963). Diplurans are divided into ten families, Campodeidae and Japygidae having the lion's share of all species in the group (Paclt 1957; Pagés 1959; 1989; Rusek 1982; Sendra 2015). The two aforementioned families and the smaller Parajapygidae have already been recorded on most of the Canary Islands (Paclt and Báez 1990, 1992; Pagés 1993; Sendra 1989, 1990; Sendra and Báez 1986). So far, a total of four Campodeidae, two Japygidae and one Parajapygidae species have been found mainly in soil habitats of this archipelago. We focused the present study in the Canaries on the lesser known subsurface habitats, i.e. the volcanic caves and the "Milieu Souterrain Superficiel" (hereafter MSS) (Juberthie et al. 1980) rather than the soil itself.

Most of the volcanic cavities are lava tubes, which usually lie a few meters below ground due to their particular origin from surface flowing lavas (Wood and Mills 1977; Wood 1979), therefore considered as part of the Shallow Subterranean Habitats (hereafter SSH) (Culver and Pipan 2014), defined as a set of mixed habitats just below the surface (soil, MSS and lava tubes among the terrestrial habitats). In spite of being relatively shallow, in volcanic terrains both lava tubes and the MSS often hold interesting cave-dwelling fauna comparable to that adapted to deeper continental karstic caves (Howarth 2008; Oromí and Martín 1992). However, no important cave-adapted species of Diplura have been found in either lava tubes or the MSS of the Canaries or Hawaii, the richest volcanic archipelagos for cave animals. Some lava tubes can occasionally be located deeper, covered by several layers of younger lava flows and commonly devoid of fauna due to the difficulty to organic matter reaching such depths. Only a few known cases of really deep tubes are suitable for adapted fauna, like the 14 million years old Cueva de Aslobas, in the south-west of Gran Canaria island (Fernández et al. 2015). Cave-adapted animals are also absent from most lava tubes in very dry areas, such as in most of the semi-arid eastern Canary Islands, with only two exceptions on Fuerteventura: Cueva del Llano and Cueva de Montaña Blanca (Rando et al. 1993; Naranjo and

Figures 1–3. Cueva de Montaña Blanca, El Castillo, Fuerteventura, Canary Islands. **1** Interior of the volcanic tube **2** entrance to the cave through a concrete tunnel **3** view of the entrance of the cave in an abandoned building.

Oromí 2011) (Figs 1–3). The Canary Islands lava tubes have no permanent water flow inside, making soil accumulation scarce, which may limit the abundance of diplurans.

Another important SSH just below the edaphic layers (i.e. soil) is the "milieu souterrain superficiel" formerly described by Juberthie et al. (1980) for non-calcareous areas of

the French Pyrenees, and later named by Culver and Pipan (2010) as "mesovoid shallow substratum" (MSS). There are different kinds of MSS, depending on the rock composition and geomorphologic origin, defined as a habitat representing the underground network of empty air-filled voids and cracks developing within multiple layers of rock fragments (Mammola et al. 2016; Ortuño et al. 2013). The MSS is usually covered by topsoil, connected with underlying deep rock cracks and caves. Fauna in MSS has been successfully surveyed in the Canaries, mostly in the typical colluvial MSS from talus deposits similar to those in continental non-volcanic terrains (Medina and Oromí 1990; Mammola et al. 2016), and in the peculiar volcanic MSS formed by lava clinker covered by a layer of protective soil (Oromí et al. 1986; Pipan et al. 2010). The latter is very abundant in recent and subrecent terrains (a few hundred thousand years) on most islands of the archipelago, providing a widespread subsurface habitat present in areas with or without lava tubes. The MSS in these islands has turned out to be almost as rich in cave-adapted fauna as the caves themselves. The few unidentified diplurans previously collected in such environments were always in colluvial MSS in the older parts of Tenerife and La Gomera, which is richer in soil and organic matter than the younger volcanic MSS (Medina and Oromí 1990, Pipan et al. 2010). Further sampling in the MSS of Gran Canaria (Fig. 4) and in an old cave on Fuerteventura has provided the new material of Campodeidae diplurans studied herein.

Material and methods

Sampling and imaging

Specimens from Fuerteventura were collected in Cueva de Montaña Blanca (Figs 1–3) using pitfall traps with propylene glycol as preservative and blue cheese as bait, and sometimes just cheese on the ground to attract them, for live collection. Specimens from Gran Canaria were collected in the MSS at Brezal del Palmital (Fig. 4) using the pitfall traps described by López and Oromí (2010), baited with raw liver or cheese and with propylene glycol as preservative. The individuals were stored in ethanol (70–75%), washed with distilled water, mounted on a slide with Marc André II solution, and examined under a phase-contrast optical microscope (Leica DMLS). The illustrations were made with a drawing tube, and measurements taken with an ocular micrometer. To determine body length, specimens were mounted *in toto* and measured from the base of the distal macrochaetae on the frontal process to the abdominal supra-anal valve. Two specimens from Cueva de Montaña Blanca coated with palladium-gold were used for SEM photography (Hitachi S-4800) and for measurements of the sensilla.

Morphological study

The morphological descriptions and abbreviations are following Condé (1955). We use the term gouge sensilla for the concavo-convexly shaped sensilla on the anten-

Figure 4. Brezal del Palmital, Gran Canaria, Canary Islands, Spain, site in the MSS where a pitfall was installed; dashed line shows the limit between epigean and hypogean (i.e. subterranean) environments.

nae according to Bareth and Condé (1981). For the position of macrosetae we adopt the abbreviations of Condé (1955): *ma*, medial-anterior *la*, lateral-anterior, *lp*, lateral-posterior and *post*, posterior.

DNA extraction, PCR ampand sequencing

Sequences of the 5' end of the cytochrome c oxidase subunit I (*COI*), a DNA fragment considered the standard DNA barcode region for Metazoa (Hebert et al. 2003),

were generated for one of the specimens collected on Fuerteventura. For this, genomic DNA was extracted using the DNeasy Tissue Kit (Qiagen) following the manufacturer's guidelines. Amplification by PCR was done using the primers LCO1490 and HCO2198 (Folmer et al. 1994) in a 25 µl total PCR volume containing 15.4 µl of purified water, 2.5 µl of 10x NH_4-based Reaction Buffer, 1.5 µl of $MgCl_2$ (3mM), 2 µl of 10 mM dNTP (2.5 mM each), 0.5 µl of BSA, 1 µl of each primer (10 µM), 0.1 µl of BIOTAQ™ DNA polymerase, and 1 µl of DNA extract. The PCR was executed with the following protocol: initial denaturing step at 95 °C for 2 min, 40 amplification cycles (94 °C for 30 s, 46 °C for 35 s, 72 °C for 45 s), and a final step at 72 °C for 5 min. PCR success was checked by running products on a 1% TAE agarose gel. Successfully amplified products were cleaned following EXO I/rAP PCR clean-up protocol and outsourced for DNA sequencing by Macrogen Inc. (https://dna.macrogen.com).

Depositories

The material examined is deposited in the following collections:

ASM	Personal collection of Alberto Sendra, Valencia, Spain
IPNA-CSIC	Invertebrates collection of the Instituto de Productos Naturales y Agrobiología (IPNA-CSIC), Tenerife, Canary Islands, Spain
MCNT	Museum of Natural History of Tenerife, Canary Islands, Spain
DZUL	Collection of the Department of Animal Biology, University of La Laguna, Canary Islands, Spain

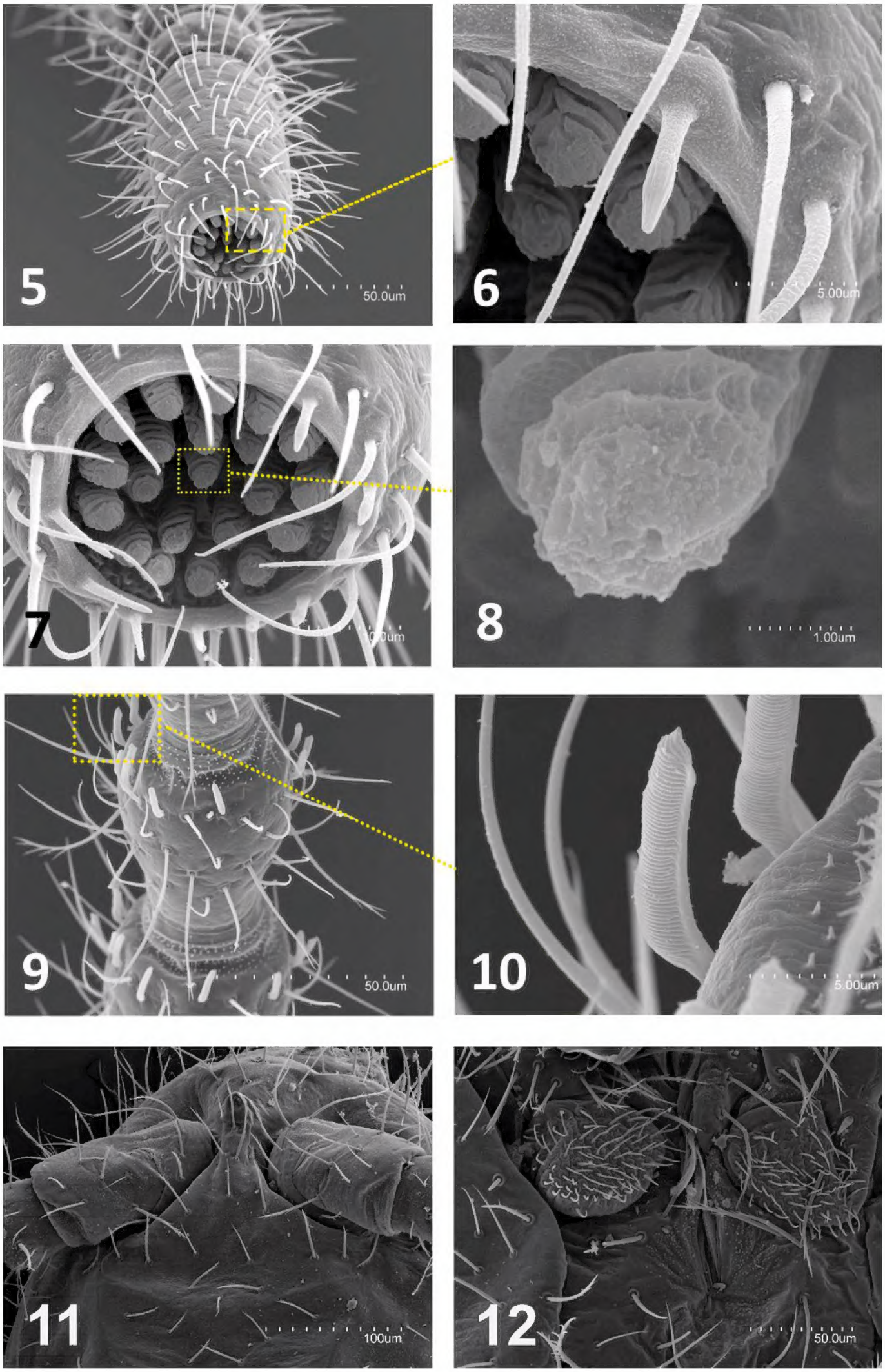
Results

Taxonomic acts

Subphylum Hexapoda Blainville, 1816
Class Entognatha Grassi, 1889
Order Diplura Börner, 1904
Suborder Rhabdura Cook, 1896
Family Campodeidae Lubbock, 1873
Subfamily Campodeinae Condé, 1956

***Remycampa herbanica* Sendra & Oromí, sp. nov.**
http://zoobank.org/5619DB84-4E4A-4293-85E7-3C6A65B9F392
Figs 5–30; Tables 1, 2

Type locality. Spain, Canary Islands, Fuerteventura: El Castillo, Montaña Blanca Cave (28°24'3.48"N, 13°52'51.08"W, 166 m a.s.l.).



Figures 5–12. *Remycampa herbanica* sp. nov. **5** Distal antennomere **6** lateral detail of the cupuliform organ with olfactory chemoreceptors **7** cupuliform organ **8** apical end of an olfactory chemoreceptor **9** medial antennomere **10** gouge sensilla **11** frontal process **12** ventral view of the head, detail of labial palps and submentum.

Type material. Holotype: 1 ♀, Spain, Canary Islands, Fuerteventura: El Castillo, Montaña Blanca Cave (28°24'3.48"N, 13°52'51.08"W, 166 m a.s.l.), 5 October 2018, A. Sendra & P. Oromí leg. (DZUL). Paratypes: 5 ♂♂, 1 juvenile (labelled M1 to M5-paratype and J-paratype), same locality as holotype, 12 July 2015, P. Oromí, H. López & B. Rodríguez leg. All type material mounted in Marc André II solution. Depositories: DZUL (2 ♂♂), IPNA-CSIC (1 ♂), ASM (2 ♂♂, 1 juvenile).

Other studied material. Same data as holotype, two specimens mounted on two separate aluminium stages and coated with palladium-gold.

Description. Body length 3.8–4.4 mm in males (n = 5), 4.2 mm in females (n = 1) and 2.2 mm in one juvenile (Table 1). Epicuticle smooth under optical microscope but slightly reticulated at high magnifications as irregular polygonal structures of variable size (Fig. 14). Body with scarce short clothing setae with one or two apical barbs on each seta (Fig. 18).

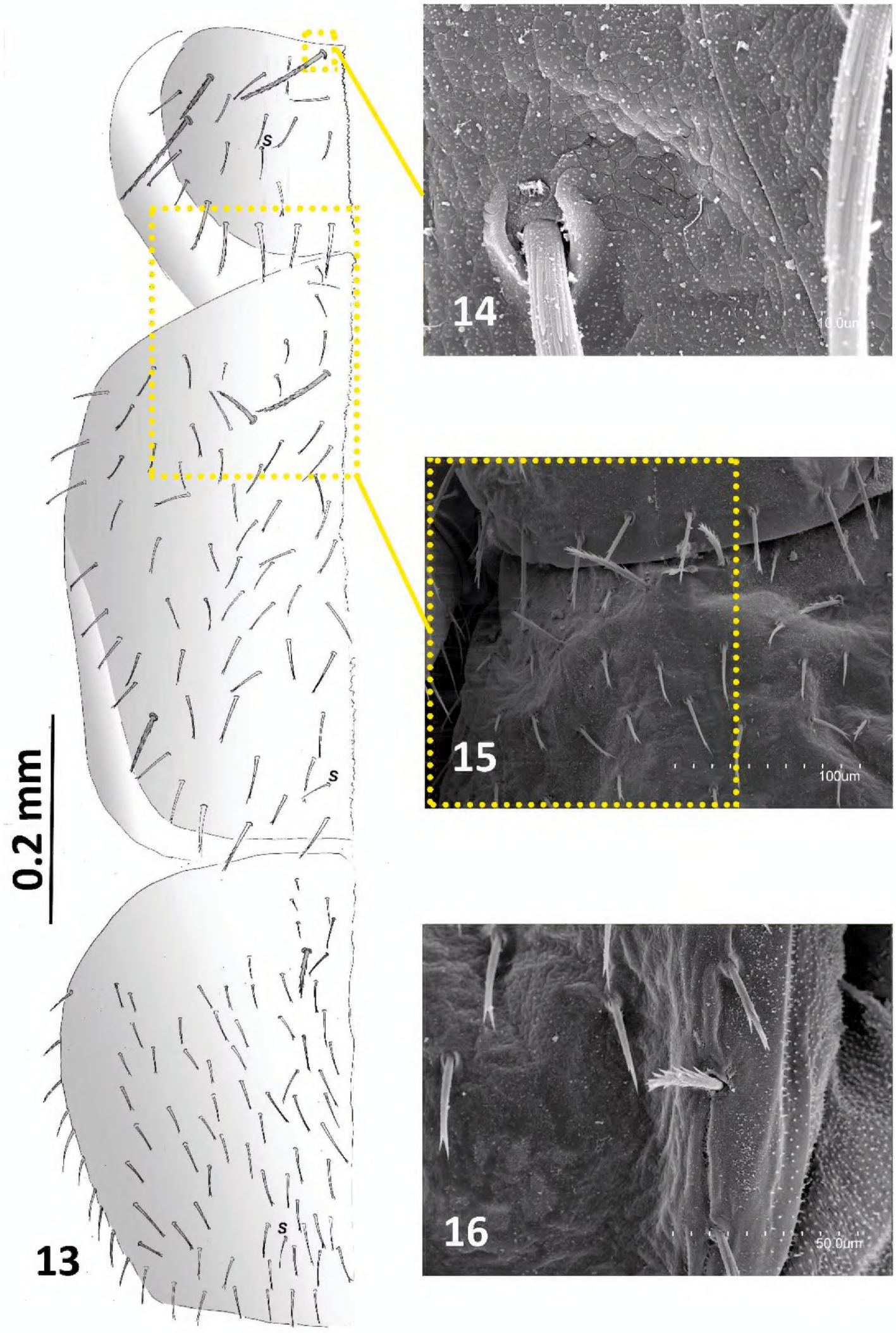
Antennae with 36 antennomeres in one complete intact antenna in the holotype; antennae 0.84× as long as the body length with medial antennomeres 2× longer than wide, as is the apical antennomere. Cupuliform organ with about 21 complex olfactory chemoreceptors arranged in two concentric circles with one in the centre, each apparently with a pile of fused plates forming a coniform structure (Figs 5–9). Distal and central antennomeres with two or three whorls of barbed macrosetae and scattered smooth setae, in addition to a single distal whorl of 8–12 short thick gouge sensilla 10 μm long (Fig. 10). These latter are more abundant on the dorsal side of the antennomere, including one or two very short coniform sensilla. Proximal antennomeres with typical trichobothria, plus a small coniform sensillum on third antennomere in ventral position.

Moderate protrusion of frontal process covered with very slightly tuberculated setae with two to five barbs on distal half (Fig. 11). Three macrosetae along each side of the line of insertion of antennomere and setae *x* with thin distal barbs; length ratios *a/i/p/x* as the 29/26/17/24 in female paratype (Fig. 11).

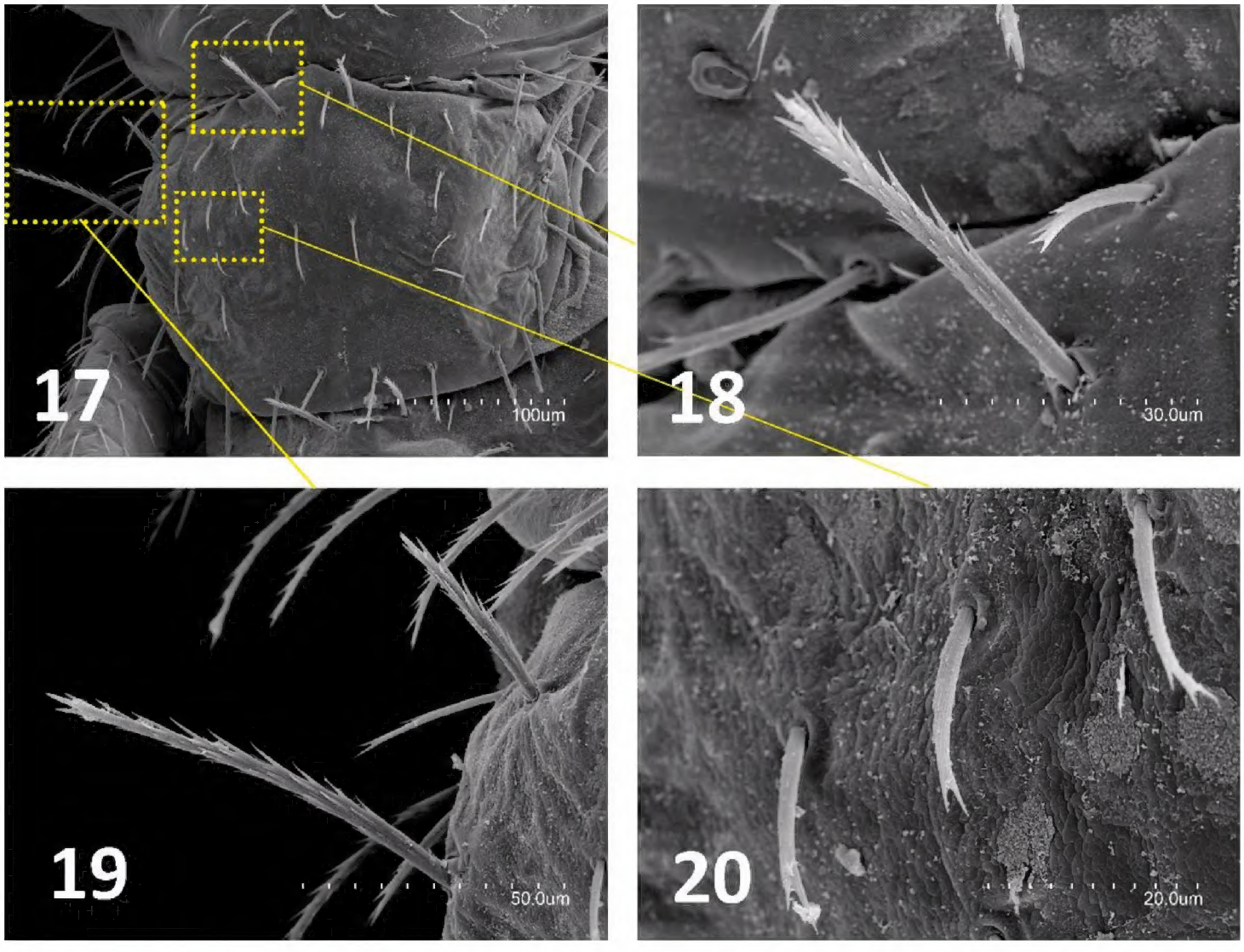
Large mandibulae with at least five teeth, the two posterior ones with a row of small denticles. Atypical labium with slight torsion to the right of the labial palps, slight elongation of the palpiform processes, and a deep groove in the middle of labium from posterior border of anterior lobe to the middle of submentum, without reaching the posterior border of labium (Fig. 12). Suboval labial palps each with small latero-external sensillum, three guard setae and up to 68 neuroglandular setae (Fig. 12).

Table 1. *Remycampa herbanica* Sendra & Oromí, sp. nov. (all units in mm except number of antennomers).

Specimen	Body length	Antennae length	Number of antennomeres	Metathoracic leg					
				Coxa	Trochanter	Femur	Tibia	Tarsus	Total leg
Paratype, ♂1	4.4	–	–	0.16	0.12	0.60	0.76	0.53	2.17
Holotype, ♀	4.2	3.54	36	0.18	0.15	0.62	0.72	0.54	2.21
Paratype, ♂2	4.0	–	–	0.18	0.12	0.52	0.80	0.50	2.12
Paratype, ♂5	3.9	–	–	0.16	0.10	0.53	0.74	0.51	2.04
Paratype, ♂3	3.8	–	–	0.15	0.10	0.51	0.70	0.49	1.95
Paratype, J	2.2	–	–	0.10	0.08	0.36	0.38	0.30	0.92



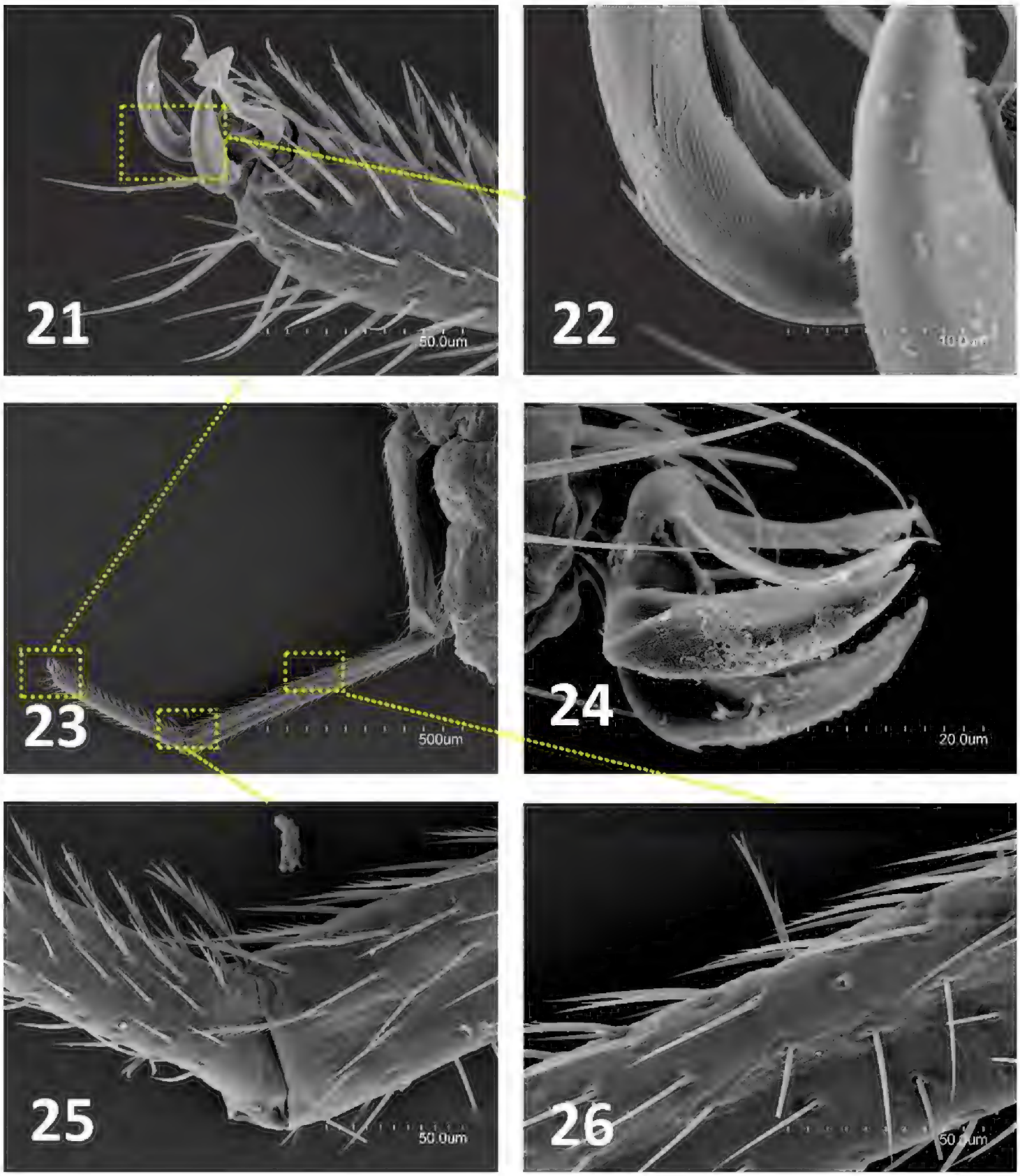
Figures 13–16. *Remycampa herbanica* sp. nov. **13** Pro-, meso- and metanotum of holotype, left side **14** detail of pronotum with medial anterior macrosetae **15** left posterior portion of pronotum and left anterior anterior portion of mesonotum **16** right posterior portion of mesonotum with lateral posterior macrosetae.



Figures 17–20. *Remycampa herbanica* sp. nov. **17** Pronotum **18** detail of pronotum with medial anterior macrosetae **19** detail of pronotum with lateral anterior and lateral posterior macrosetae **20** detail of pronotum with clothing setae.

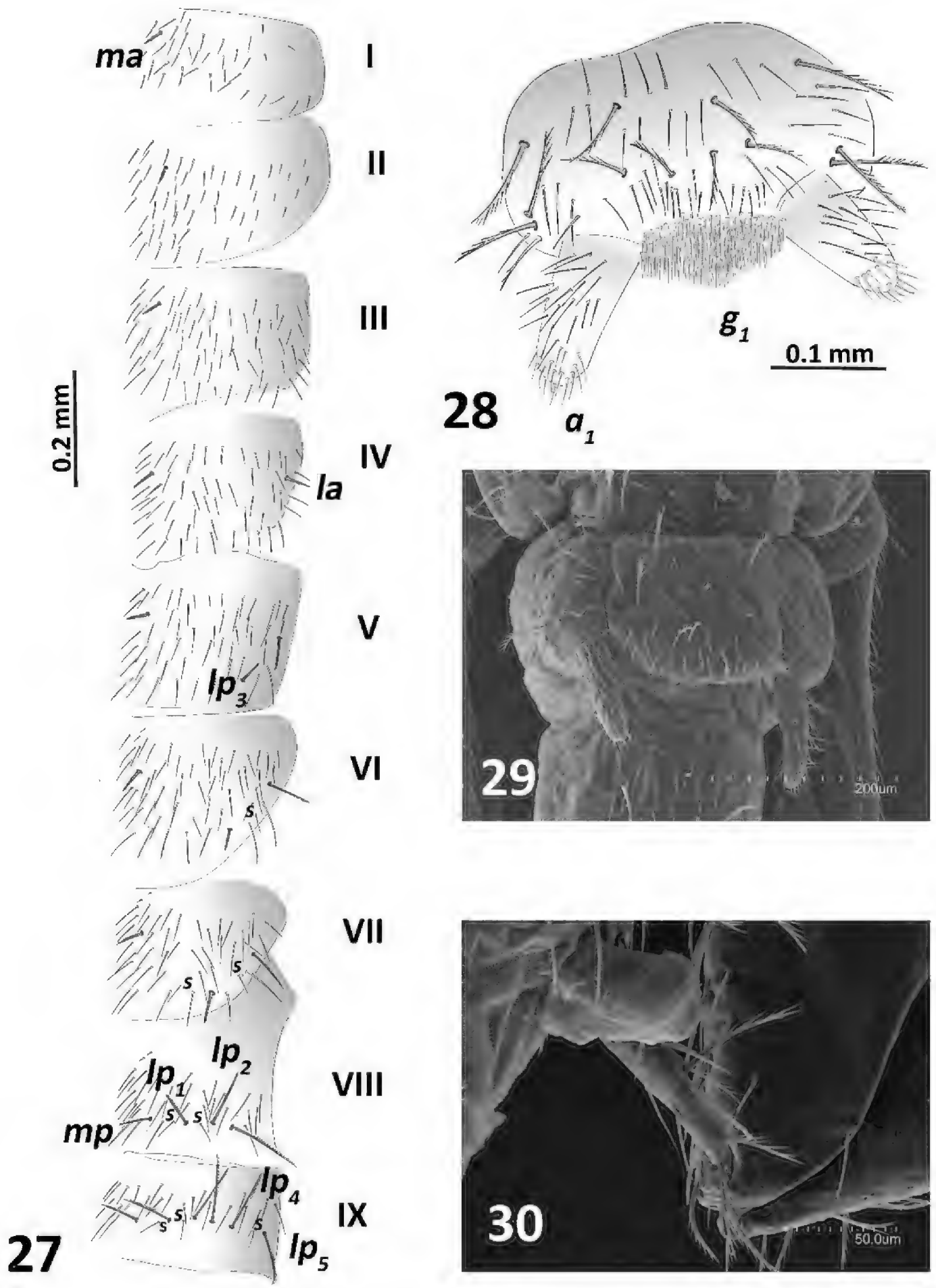
Thoracic macroseta distribution (Figs 13–20): pronotum and mesonotum with 1+1 *ma*, 1+1 *la*, 1+1 *lp* macrosetae; metanotum with 1+1 *ma* macrosetae. All macrosetae short and slightly thick with short barbs along basal two-thirds of each seta; marginal setae longer and more barbed than clothing setae (Figs 13–20). Legs elongated, metathoracic legs reaching abdominal segment IX, about 0.5× as long as the body length (Figs 21–26; Table 1). Tibia always longer than femur or tarsus (Table 1). Femorae I–III each with one short thick dorsal macroseta with a few barbs. Calcars with long barbs throughout one side (Fig. 25). Tibiae I–III with two short ventral macrosetae with two to four distal barbs; some paratypes with three sternal tibial macrosetae on the metathoracic leg (Figs 23, 26). Two rows of ventral barbed setae with two lines each of two to five barbs (Figs 21, 25). Three smooth dorsal distal tarsal setae longer than the rest (Fig. 21). Subequal claws with a lateral expansion curved towards the two ventral sides. Smooth laminar telotarsal processes curved along and ending in a slightly wide expansion with a narrow prolongation on one side, a unique shape among diplurans (Figs 21, 22, 25).

Distribution of abdominal macrosetae on tergites (Fig. 27): 1+1 *ma* on I–III; 1+1 *ma*, 1+1 *la* on IV, 1+1 *ma*, 1+1 *la*, 1+1 lp_3 on V–VII; 1+1 *mp*, 3+3 $lp_{1\text{-}3}$ on VIII; and 1+1 *mp*, 5+5 $lp_{1\text{-}5}$ on IX abdominal segment. All tergal abdominal macrosetae short, slightly thick with thin short barbs being *ma* and *mp* the shortest.



Figures 21–26. *Remycampa herbanica* sp. nov. metathoracic leg. **21** Distal portion of the tarsus **22** detail of claws **23** right metathoracic leg **24** pretarsus **25** joint between tibia and tarsus with a calcar **26** medial portion of tibia with ventral macrosetae.

Urosternite I with 6+6 macrosetae (Figs 28, 29); urosternites II to VII with 4+4 macrosetae; urosternite VIII with 1+1 macrosetae; urosternal macrosetae of medium length or longer, with a few long barbs in one single row along the distal half to four-fifths. Stylus with an apical, a subapical and a ventromedial seta with a few long barbs arranged in one row along the distal four-fifths (Fig. 30). Cerci more than 2× as long as the body length, 2.1× as long as the body in the only apparently intact cercus of the holotype; with 27 primary articles, not counting the multi-divided basal article (Table 2). Length



Figures 27–30. *Remycampa herbanica* sp. nov. **27** Dorsal view of abdomen, right side, holotype **28** male first urosternite, paratype **29** female first urosternite **30** left stylus and vesicle of the fifth urosternite. s = setiform sensillum).

of cerci increases very slightly from the proximal to distal articles; they are covered with a whorl of alternate smooth thin macrosetae and smooth thin setae, and a whorl of shorter smooth thin setae at the end of each primary article. These whorls, except the apical one, increase from one to four from the proximal to distal primary articles.

Table 2. *Remycampa herbanica* Sendra & Oromí, sp. nov. (all units in mm except number cercal articles and basal secondary articles).

								Cerci, articles length							
Divisions basal article	**Basal**	**1st**	**2nd**	**3tr**	**4th**	**5th**	**6th**	**7th**	**8th**	**9th**	**10th**	**11th**	**12th**	**13th**	**14th**
10	1.25	0.16	0.18	0.20	0.19	0.19	0.20	0.23	0.22	0.24	0.26	0.26	0.25	0.26	0.28
10	1.58	0.18	0.18	0.18	0.18	0.21	0.22	0.23	0.24	0.25	0.28	0.27	0.26	0.27	0.29
Divisions basal article	**15th**	**16th**	**17th**	**18th**	**19th**	**20th**	**21th**	**22th**	**23th**	**24th**	**25th**	**26th**	**27th**	**Total cercus**	
10	0.28	0.30	0.30	0.30	0.32	0.32	0.30	0.34	0.32	0.34	0.35	0.33	0.30	8.66	
10	0.28	0.29	0.29	0.31	0.31	0.33	–	–	–	–	–	–	–	–	

Female urosternite I with slim cylindrical appendages, each bearing up to seven glandular a_1 setae in a distal field (Fig. 29).

Male urosternite I with short coniform appendages, each bearing about 13 glandular a_1 setae in a distal field; posterior edge occupied by a large but narrow field of cramped up to 190 glandular g_1 setae (Fig. 28).

Etymology. Referring to Herbania, the ancient name of Fuerteventura, the only island on which it has been found.

Molecular data. The barcode sequence of one specimen of *R. herbanica* (code 112BC) has been registered in GenBank with the ascension number MN729498.

Phylogenetic analyses. Available *COI* barcode sequences of Diplura stored in BOLD were retrieved (search for Diplura on 14th November 2019 at http://www.boldsystems.org/index.php/) to identify the species closest to *R. herbanica*. After excluding redundant sequences for several taxa, a total of 46 sequences, representing approximately 28 species from at least 10 genera were retained. They were then aligned with the newly generated *R. herbanica* sequence using the MAFFT E-INS-I algorithm (Katoh et al. 2002). A preliminary maximum likelihood tree was generated using the Fast Tree 2.1.5 (Price et al. 2009) tool in Geneious 7.1.9 (Kearse et al. 2012) to identify taxa closely related to *R. herbanica*.

The genetic results do not show well supported relationships of *R. herbanica* with the other diplurans with barcode sequences in BOLD. Based on this preliminary result we only can confirm genetically that this new species belongs to the family Campodeidae.

Spaniocampa relicta Sendra & López, sp. nov.

http://zoobank.org/588E7856-C77B-45F1-9D86-C476B4C37C1C
Figs 31–34

Type locality. Spain, Canary Islands, Gran Canaria: Brezal del Palmital (28°6'33.58"N, 15°36'1.73"W, 551 m a.s.l.).

Type material. Holotype: 1 ♀, Spain, Canary Islands, Gran Canaria: Brezal del Palmital (MSS3) (28°6'33.58"N, 15°36'1.73"W, 551 m a.s.l.), 4 July 2010, H. López leg (DZUL). Paratypes: same data as holotype, 1 ♀, 1♂ (ASM). All type material mounted in Marc André II solution.

Description. Body length 3.4 mm (paratype) and 4.1 mm (holotype) in females, and 3.5 mm (paratype) in male. Epicuticle with small microdenticles under optical microscope on dorsal side of nota and legs. Body with smooth clothing setae.

Broken antennae on the three types; medial antennomeres (antennomere XII intact) as long as wide, a single distal whorl of 8–10 short and thin gouge sensilla 12 µm long. Proximal antennomeres with typical trichobothria plus a bacilliform sensillum on third antennomere in ventral position.

Plain frontal process with one anterior and three posterior smooth setae; length ratios of *a/p* as 53/23 in holotype. The three macrosetae along each side of the line of insertion of antennomere with thin distal barbs and length ratios of *a/i/p* as 17/27/16 in holotype; no *x* setae observed; Each suboval labial palp has a small latero-external subcylindrical sensillum; two guard setae, up to three simple setae on anterior border and up to 70 neuroglandular setae in holotype.

Non-thoracic macrosetae on pronotum, mesonotum and metanotum; short slightly thick marginal setae with very thin or smooth apical barbs (Fig. 31). Metathoracic legs reaching abdominal segment VII. Femora without dorsal macrosetae. Tibiae I–III without typical ventral barbs but with a short ventral apical one with a few thin distal barbs; calcars with three to six thin barbs along one side. Two dorsal tarsal smooth setae similar to clothing setae, but much longer. Subequal claws, slightly wider at the base and regularly curved. Smooth setiform telotarsal processes overpassing the end of the claws.

Distribution of abdominal macrosetae on tergites (Fig. 34): 1+1 lp_3 on urotergite VIII; 3+3 $lp_{3,4,5}$ on abdominal segment IX, and 4+4 macrosetae on abdominal segment X; all these macrosetae long and well-differentiated with thin barbs along the distal third to three-quarters.

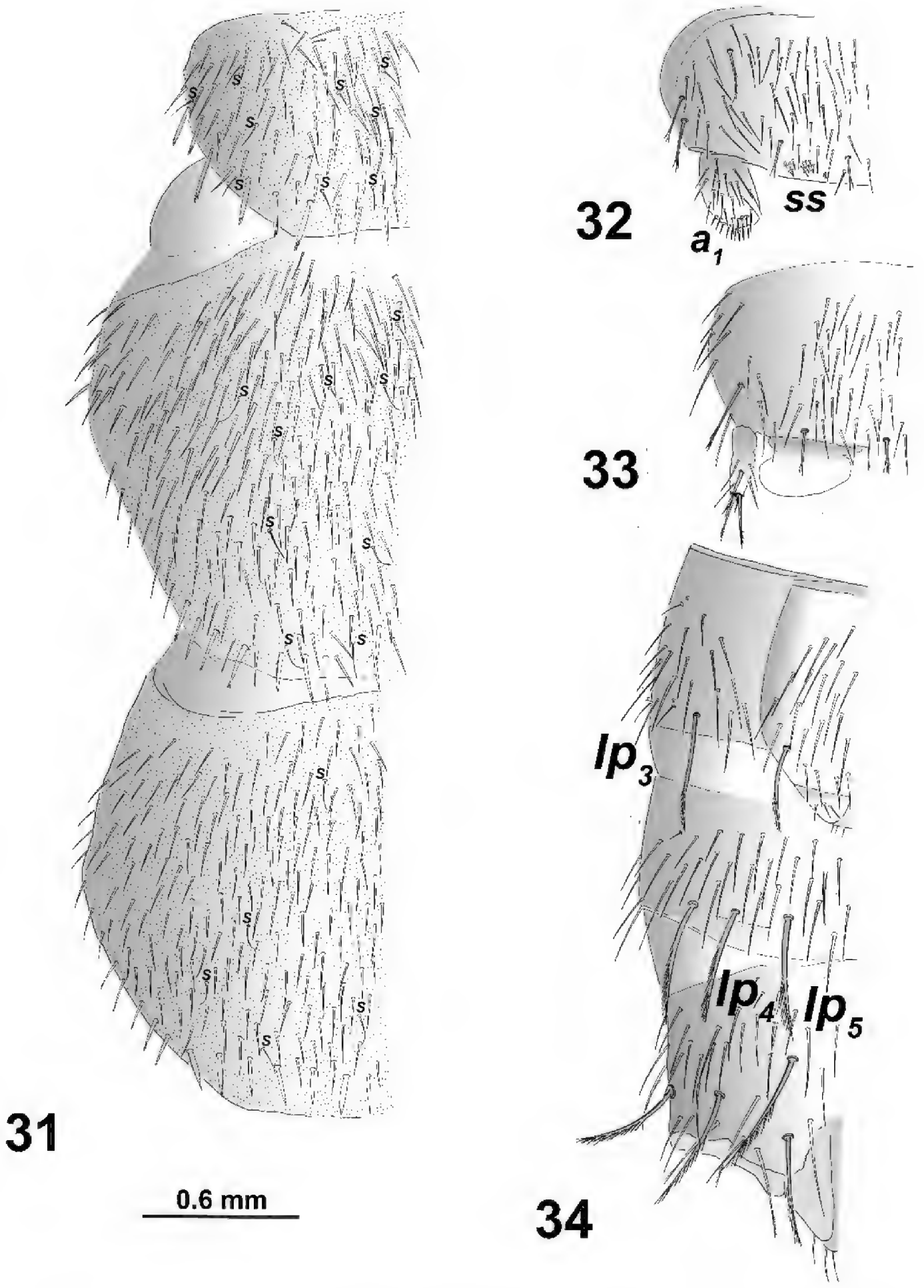
Urosternite I with 5+5 macrosetae; urosternites II to VII with 3+3 macrosetae; urosternite VIII with 1+1 macrosetae; urosternal macrosetae short to middle size with one to five apical to distal barbs (Figs 32, 33).

Stylus with an apical, a subapical and a ventromedial setae with a few distal thin long barbs, more abundant on the ventromedial seta (Fig. 33). Cerci absent in the studied specimens.

Female urosternite I with short subcylindrical appendages, each bearing up to 14 glandular a_1 setae in a distal field. The posterior border of the urosternite bears three or four groups of small setiform setae with between two and ten units (Fig. 32).

Male urosternite I with short thick appendages, each bearing about 35 glandular a_1 setae in two apparently distal fields; posterior edge slightly enlarged at both sides of the first urosternite with a glandular field of about 140 glandular g_1 setae arranged in up to six rows.

Etymology. The specific epithet *relicta* refers to two situations affecting this new species: i) it has been discovered in a relict patch of laurel forest on Gran Canaria; ii) it is a relict species of a genus also distributed on the Republic of Guinea with one known extant species.



Figures 31–34. *Spaniocampa relicta* sp. nov. **31** Pro-, meso- and metanotum of holotype **32** female first ursoternite, right side, paratype **33** fourth urosternite, right side, female paratype **34** eighth to tenth abdominal segments, ventral view, right side, holotype.

Discussion

Phyletic affinities

The substantially cave-adapted *Remycampa herbanica* sp. nov. is certainly related to the monotypic genus *Remycampa* Condé, 1952, due to several important taxonomic features including similarities in their atypical labium, secondary sexual characters, lateral telotarsal processes and distribution of macrosetae. The only species known so far, *Remycampa launeyi* Condé, 1953, has a distribution area in northeast Morocco and some of the Canary Islands (Sendra 1989), has extended to the islands of El Hierro, Tenerife, Gran Canaria, and Lanzarote. *R. herbanica* has been collected in a volcanic lava tube of Fuerteventura. Being only 11 km from Lanzarote one can postulate that *R. launeyi* might be present also in soils or MSS of Fuerteventura. Both islands were joined during the last glaciation (Fernández-Palacios et al. 2015) and had and have a similar climate. The most visible differences between *R. launeyi* and *R. herbanica* are in the cave-adapted features of the new species, which has a larger, more elongated body and appendages with cerci 2.1× longer than the body length and with 28 articles (Table 2), and with metathoracic tibiae bearing 2–3 sternal macrosetae. Furthermore, each apical antennomere has a large cupuliform organ with quite remarkably for the high number of olfactory chemoreceptors (up to 21) with a unique coniform shape (Figs 5–8). Other noteworthy morphological differences are: shorter and thicker macrosetae and shorter clothing setae with apical barbs in *R. herbanica*; differences in the shape of their lateral telotarsal processes, with trapezoidal endings in *R. launeyi* and round with a thin expansion in *R. herbanica* (Figs 21, 22, 24); Condé 1953: figures 3C, D and E); absence of lateral posterior macrosetae on metanotum in *R. herbanica*; absence of 1+1 lateral posterior macrosetae on third and fourth urotergites in *R. herbanica*; and finally differences between their labial pieces with a strong torsion to the right of labial palps and enlargement of the groove in the middle of the labium in *R. launeyi* compared with a less pronounced and smaller groove in *R. herbanica* (Fig. 12).

Remycampa is a peculiar genus with an unclear relation to other genera of Campodeinae, but with certain affinities with the tachycampoid phyletic lineage. It is probably more closely related to the two known cave-adapted tachycampoid genera living in caves of northwest Africa: *Jeannelicampa* Condé, 1952 from Oran in the Tell Atlas, Algeria, and *Tachycampa* Silvestri, 1936 from karst areas near Taza in the Middle Atlas, Morocco. Like *R. herbanica*, these two genera lack some thoracic macrosetae, short thoracic macrosetae and lateral expansions on the claws. Nevertheless, new taxonomic tools are needed to unravel the natural phylogenetic relations within Campodeinae and tachycampoid genera (Sendra et al. 2020).

It is difficult to determine the exact systematic position of *Spaniocampa relicta* sp. nov., not because of the broken antennae or missing cerci that cannot be described, but rather the lack of fresh specimens of the two closely related genera and their species. We refer to the monospecific *Spaniocampa* Silvestri, 1933 from Kakoulima massif (Republic of Guinea) and *Ombrocampa* Paclt, 1957 that, according to Paclt (1957), includes the three related species *O. dahli* Condé, 1956 and *O. nyongensis* Condé, 1956

from Nyong (Cameroon) and *O. depauperata* (Silvestri, 1918) from Mount Kenya (Kenya). They are all soil-dwelling, whereas *Spaniocampa relicta* was found in colluvial MSS. All these species have in common with *S. relicta* a low number of thoracic and abdominal macrosetae, including no dorsal macrosetae on femorae and no ventral ones on tibiae (with the exception of one short ventral tibial macroseta in *Spaniocampa prima* Silvestri, 1933). Furthermore, S. *prima* shares with *S. relicta* sp. nov. the total absence of notal macrosetae (Fig. 31) and similarities in the distribution of abdominal macrosetae: 2+2 lateral posterior macrosetae on eighth urotergite and ninth abdominal segment in *S. prima* and 1+1 lateral posterior on eighth urotergite and 3+3 lateral posterior on ninth abdominal segment in *S. relicta* (Fig. 34). Further differences to *S. prima* were also found in the number of urosternal setae, with: 8+8 macrosetae on first urosternite (this number could be reduced to 7+7, since Silvestri considered some barbed setae in latero-posterior position as macrosetae) and 4+4 macrosetae on second to seventh urosternites in *S. prima* compared with only 5+5 and 3+3 macrosetae in *S. relicta* sp. nov.

It is worth mentioning the presence of small setae arranged in groups on the posterior border of the first urosternite in females; their function is unknown, though apparently non-glandular, and they have never been described in any other species of the campodeid family.

Dipluran fauna and their habitats

The Canary Islands have a wide range of SSH in their volcanic landscapes: soils, MSS, and young and old lava tubes with a rich biodiversity (Oromí 2004). Diplurans had been collected in soil and MSS but not in lava tubes until now (Paclt and Báez 1990, 1992; Pagés 1993; Sendra 1989, 1990; Sendra and Báez 1986). Focusing on Campodeidae, six species of the subfamily Campodeinae are present in the Canary Islands. Two species of the genus *Campodea* are widespread in the Euromediterranean region and beyond: *Campodea* (*Campodea*) *fragilis* Meinert, 1865 and *Campodea* (*Monocampa*) *devoniensis* Bagnall, 1918. Another two have more limited distribution areas: *Podocampa ceballosi* (Silvestri, 1932) in the Iberian Peninsula and northwest Africa, *Remycampa launeyi* Condé, 1952 limited to north-west Africa. The two new species *Spaniocampa relicta* sp. nov. and *Remycampa herbanica* sp. nov. are endemic to the Canaries. In relation with their habitats, *Campodea fragilis*, *C. devoniensis*, *Podocampa ceballosi* and *Remycampa launeyi* are frequently found in soil and are also present in the MSS as *Spaniocampa relicta* sp. nov. And, *Remycampa herbanica* sp. nov. is the only species occurring in lava tubes and showing cave-adapted features, also known as troglomorphic traits, as a result of its obligate lifestyle. It has been collected exclusively in Cueva de Montaña Blanca, one of the few lava tubes on Fuerteventura suitable for such adapted fauna (Figs 1–3). The presence of cave-adapted diplurans in other lava tubes around the world is not uncommon. Ferguson (1992) provided many localities from the USA, and Borges and Oromí (1994) reported the presence of one species in Gruta do Esqueleto, São Miguel island, Azores. Sendra et al. (2016) described a spe-

cies from Mexican volcanic caves, and an interesting cave-adapted *Lepidocampa* was reported from Reunion in the Indian Ocean (Sendra et al. 2017).

The special case of Cueva Blanca

Fuerteventura has a maximum sub-aerial age of 22 Ma, an exceptional span for a volcanic island, probably due to its extremely slow subsidence into the sea, compared to other volcanic archipelagos (Fernández-Palacios et al. 2011). For this reason, together with its scarce volcanic activity over the last million years, the island is highly eroded and most of the extant caves are dry and often silted with clay, thus being unsuitable to hold adapted troglobiont fauna. Only two of these lava tubes (Cueva del Llano and Cueva de Montaña Blanca, 27 km apart from each other) have appropriate humidity conditions for this fauna that includes eight troglobiont arthropod species which are all endemic to the island and often with no related species in the archipelago. Only the nicoletiid Zygentoma *Coletinia majorensis* Molero, Gaju, López, Oromí & Bach, 2013 inhabits both caves, the remaining seven species being exclusive to one or the other (Rambla 1993; Molero et al. 2013). The habitat of both caves is highly threatened. Cueva del Llano is a show cave owned by the local government, and many houses are built on the surface surrounding the cave, in spite of the exclusive presence of the officially protected harvestman *Maiorerus randoi* Rambla, 1993. Cueva de Montaña Blanca is the only known place where *Remycampa herbanica* sp. nov. and some undescribed troglobiont invertebrates occur (two weevils, one pseudoscorpion and one spider), and its entrance is within an unfinished abandoned four-story building in a tourist resort. The situation is critical for these cave-dwelling species given that most of the Fuerteventura underground is very dry, there is hardly any area of MSS, and therefore their inhabitable environment is highly limited to small distantly dispersed spots.

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